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*Indian Standard*

# CODE OF PRACTICE FOR PLANNING AND DESIGN OF PORTS AND HARBOURS

## PART 4 GENERAL DESIGN CONSIDERATIONS

*( Second Revision )*

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## FOREWORD

This Indian Standard ( Part 4 ) ( Second Revision ) was adopted by the Bureau of Indian Standards on 17 February 1989, after the draft finalized by the Ports and Harbours Sectional Committee had been approved by the Civil Engineering Division Council.

This standard was first published in 1969 covering design and construction aspects of sheet pile retaining walls, the provisions of which are now being covered in separate series relating to design and construction of ports and harbours. Subsequently, this standard was revised in 1979 to cover general design consideration of ports and harbour structures. This standard is one of the series of standards formulated to cover various aspects of foundations for marine structures.

The revision of this standard has been taken up to incorporate further modifications necessary in the light of comments received from the users of this standard. Clauses on method of design have been modified keeping in view the fact that the load factor method is replaced by the limit state method in IS 456 : 1978 'Code of practice for plain and reinforced concrete'. Also the clause specifying the requirements of concrete has been updated.

For the purpose of deciding whether a particular requirement of this standard is complied with, the final value, observed or calculated, expressing the result of a test or analysis, shall be rounded off in accordance with IS 2 : 1960 'Rules for rounding off numerical values ( *revised* )'. The number of significant places retained in the rounded off value should be the same as that of the specified value in this standard.

*Indian Standard*

# CODE OF PRACTICE FOR PLANNING AND DESIGN OF PORTS AND HARBOURS

## PART 4 GENERAL DESIGN CONSIDERATIONS

*( Second Revision )*

## 1 SCOPE

This standard ( Part 4 ) deals with general design considerations for dock and harbour structures.

## 2 REFERENCES

The Indian Standards listed in Annex A are necessary adjuncts to this standard.

## 3 TERMINOLOGY

For the purpose of this standard, the definitions of terms given in IS 7314 : 1974 shall apply.

## 4 LOADS, FORCES AND STRESSES

**4.1** The loads, forces and stresses to be considered in designing the structures are the following:

a) Dead load ( DL );
b) Vertical live load;
c) Impact or dynamic effect of live load;
d) Forces caused by the tractive effort or breaking of vehicles, cranes, ship loader/unloader, material handling equipment, etc;
e) Centrifugal forces of vehicles moving on curve;
f) Earth pressure;
g) Hydrostatic and hydrodynamic forces;
h) Berthing forces from vessels;
j) Mooring forces;
k) Forces due to wind;
m) Secondary stresses ( stresses due to shrinkage, creep, temperature, etc, as applicable );
n) Erection stage stresses;
p) Live load ( LL ); and
q) Seismic forces.

**4.2** The above mentioned loads, forces and stresses should be worked out on the basis of provisions in IS 4651 ( Part 3 ) : 1974 and other relevant Indian Standards.

## 5 COMBINATION OF LOADS, FORCES AND STRESSES

**5.1** All members shall be designed to sustain safely the effect of the combination of various loads, forces and stresses ( specified in **4.1** ) that can possibly co-exist. All calculations shall distinctly tabulate the various combinations of above loads and stresses covered by the design. The load combinations given in Tables 1 and 2 should be considered.

**Table 1 Partial Safety Factors for Loads in Limit State Design**

| Loading | Partial Safety Factor | | | | | |
|---|---|---|---|---|---|---|
| | Limit State Serviceability | | Limit State of Collapse | | | |
| Dead load [ **4.1**( a ) ] | 1·0 | 1·0 | 1·5 | 1·2 ( or 0·9 ) | 1·2 ( or 0·9 ) | 1·2 ( or 0·9 ) |
| Vertical live load [ **4.1**( b ) ] | 1·0 | 1·0 | 1·5 | 1·2 ( or 0·9 ) | 1·2 ( or 0·9 ) | 1·2 ( or 0·9 ) |
| Earth pressure [ **4.1**( f ) ] | 1·0 | 1·0 | 1·0 | 1·0 | 1·0 | 1·0 |
| Hydrostatic and hydrodynamic forces [ **4.1**( g ) ] | 1·0 | 1·0 | 1·0 | 1·2 | 1·0 | 1·0 |
| Berthing and mooring forces [ **4.1**( h ) and **4.1**( j ) ] | — | 1·0 | 1·5 | — | — | — |
| Secondary stresses [ **4.1**( m ) ] | 1·0 | — | — | — | — | — |
| Wind forces [ **4.1**( k ) ] | — | — | — | — | 1·5 | — |
| Seismic forces [ **4.1**( p ) ] | — | — | — | — | — | 1·5 |

NOTE — For the limit states of serviceability, the values given in this table are applicable for short terms effects. While assessing the long term effects due to creep, the dead load and the part of the live load, likely to be permanent, may only be considered.

**Table 2 Increase in Permissible Stresses**

( *Clauses* 5.1 *and* 7.1.2 )

| Sl No. | Combination of Loads | Increase in Permissible Stress | | Increase in Allowable Bearing Pressure |
|---|---|---|---|---|
| | | Reinforced Concrete | Other Materials Such as Steel and Timber | |
| i) | DL + LL + impact of breaking or traction or vehicles + centrifugal forces of vehicles | Nil | Nil | Nil |
| ii) | DL+LL with impact, breaking or tractive and centrifugal forces + earth pressure, percent | 15 | 15 | 15 |
| iii) | DL with/without LL including impact, breaking or tractive and centrifugal forces + earth pressure + hydrodynamic and hydrostatic forces + berthing and mooring forces, percent | 25 | 33 1/3 | 25 |
| iv) | Wind forces on structures + load combination of ( i ), ( ii ) or ( iii ) | *see* IS 875 ( Part 3 ) : 1987 | | |
| v) | Seismic forces+load combination ( i ), ( ii ) or ( iii ) | *see* IS 1893 : 1984 | | |
| vi) | Secondary stresses + load combination of ( i ), percent | 15 | 15 | 15 |
| vii) | Erection stage stresses with DL and appropriate LL +earth pressure + hydrostatic and hydrodynamic forces + wind forces, percent | 15 | 33 1/3 | 25 |

**5.2** Crane/machine operating loads [ **4.1**( b ), **4.1**( d ) and **4.1**( e ) ] along with dead load [ **4.1**( a ) ], combined with wind load specified by the manufacturer or the normal wheel load with maximum wind load as specified in IS 875 ( Part 3 ) : 1987, whichever is more severe, should be taken for design purposes.

**5.3** As berthing of vessel is deemed to be done in relatively calm conditions, the berthing forces may not be considered to occur simultaneously with crane/machine operating load [ **4.1**( b ), **4.1**( d ) and **4.1**( e ) wind loads **4.1** k ) or seismic forces **4.1**( q ) ].

**5.4** Wind load [ **4.1**( k ) ] and seismic forces [**4.1**( q ) ] need not be deemed to act simultaneously.

**5.5** Seismic forces [ **4.1**( q ) ] need not be combined with erection stage stresses [ **4.1**( n ) ].

## 6 METHOD OF DESIGN

**6.1** Structures and structural elements may be designed by any of the following methods:

a) Limit state method, and

b) Working stress method.

**6.1.1** RCC and prestressed concrete members can be designed by any of the above two methods whereas for designing structures with other material, working stress method should be adhered to.

### 6.2 Limit State Method

In the limit state method of design, a structure is considered unfit for use when it reaches a particular state called limit state at which it ceases to fulfil the function or satisfy the conditions for which it is designed. The structure shall be designed to withstand safely all loads liable to act throughout its life and it shall also satisfy the serviceability requirements, such as, limitations on deflection and cracking, etc.

**6.2.1** All relevant limit states shall be considered in design to ensure an adequate degree of safety and serviceability. In general, the structure shall be designed on the basis of the most critical limit state and shall be checked for other limit states.

**6.2.2** *Partial Safety Factors for Loads*

The values for the partial safety factor in Table 1 shall normally be used.

**6.2.3** *Partial Safety Factor for Material Strength*

When assessing the strength of a structure or structural member for the limit state of collapse, the values of partial safety factors shall be taken as 1·5 for concrete and 1·15 for steel.

### 6.3 Working Stress Method

Working stress method or permissible stress method may also be adopted in the designs till such time the complete changeover to the limit state method is made in other relevant Indian Standards on the subject. However as the limit state method is more rational and adoptable, the designs may be carried out by limit state method. Limit state method affords easy

calculation in the case of circular columns which involve a complicated procedure under working stress method.

## 7 PERMISSIBLE STRESSES

**7.1** The following permissible stresses shall be adopted for the working load method of design.

**7.1.1** When the load items mentioned in **4.1**( a ) to **4.1**( e ) are considered for possible appropriate combination, the following standard shall be applicable, subject to the stipulations contained in **7.1.2**.

a) For reinforced concrete structural members, the permissible stresses shall be as specified in IS 456 : 1978.

b) For prestressed concrete structural members, the permissible stresses shall conform to those specified in IS 1343 : 1980.

c) For structural steel members, the permissible stresses shall be as specified in IS 800 : 1984.

d) For timber structural members, the permissible stresses shall be as specified in IS 883 : 1970.

e) For timber or concrete piles, the safe bearing capacity, and/or factor of safety shall be in accordance with IS 2911 ( Part 2 ) : 1980 and IS 2911 ( Part 1/Sec 1 to 3 ) : 1979.

**7.1.2** *Increase in Permissible Stresses*

Under various combinations of loading, the appropriate permissible stresses of bearing pressures may be exceeded up to the limits as indicated in Table 2 provided in no case does the stress exceed the yield stress or 0·2 percent of the proof stress of the material concerned.

## 8 CHOICE OF CONSTRUCTION MATERIAL

**8.1** The basic criteria adopted in the general choice of construction material, such as, easy availability, easy working, mechanical properties suited to the purpose for which it is to be used and economic considerations, hold equally good for dock and harbour structures. The durability under the environmental condition, however, is of particular importance in these marine structures. The aggressive action of sea water and/or the marine environment of the principal construction materials, such as, steel, concrete and timber requires special attention.

### 8.2 Steel

**8.2.1** Unless otherwise specified, the steel shall conform to IS 226 : 1975 or IS 2062 : 1984.

**8.2.2** The corrosion of steel varies in different conditions of sea air or sea water exposure. Severe corrosion, however, occurs in saline water and undermarine growth, specially in the splash zone and in the reaches of the tidal range with alternate wetting and drying. Steel buried in ground is also subjected to corrosion under certain conditions.

**8.2.3** Any one or a combination of the following remedial measures may be taken against the corrosion:

a) *Protective Coatings*

Protective coatings form a barrier to the environmental exposure and thereby delay the corrosion. These barriers invariably break down after a number of years, specially under the suction and growth of barnacles. The choice of coatings, method of application, thickness of coats, possibility of recoating, etc, are important in ensuring optimum performance of coatings.

b) *Cathodic Protection*

Corrosion of steel completely immersed under water or buried in ground ( where possibility of electrolytic corrosion exists ) can be substantially eliminated, and corrosion of steel alternatively exposed to wet and dry condition can be significantly protected by cathodic protection using an impressed current system or sacrificial anode system.

c) *Increased Section/Reduced Stresses*

Where the above mentioned measures are not practical or their maintenance a doubtful, extra thickness of metal or section may be considered for providing an economic solution.

The actual recommendations as to the minimum metal thickness depend upon the nature of the structure and its projected life. As a general rule, it may be considered that any mild steel used in marine structure, should have a minimum thickness of 6 mm when cathodic protection is provided, and a minimum thickness of 10 mm when cathodic protection is not provided. In any case, no structural steel should be used in marine conditions without protective coatings.

d) *Use of Special Steel*

Special alloy steels, such as, like those with 2 percent copper content can significantly arrest corrosion.

e) *Jacketting with Concrete or Other Suitable Synthetic Material*

Special care has to be taken in the splash zone where the protection could be given by a concrete lining applied by guniting or by jacketting with suitable synthetic material.

### 8.3 Concrete

**8.3.1** Concrete has extensive use in harbour structures, such as, dock walls and floors, piles, sheet piles, caissons and monoliths, deck structures for jetties and wharves and breakwater

armour blocks, apart from the use in dock buildings and in other structures above ground.

**8.3.2** The concrete structures built in aggressive environment are subject to attack by sea water penetrating into the mass. Concrete shall be made impermeable to such a degree that it is not penetrated by the constituents of sea water. The most dense concrete will give the best result. Concrete grade not less than M 30 for RCC and M 40 for prestressed concrete construction shall be used. Concrete grade not less than M 15 shall be used in mass concrete construction.

**8.3.3** The use of special type of cement and the total cement content in concrete also require careful consideration. Sulphate resistant cement or blast furnace slag cement ( *see* IS 455 : 1976 and IS 1489 : 1976 ) should preferably be used for marine structures wherever available. As an alternative, ordinary Portland cement may be used provided a higher grade of concrete than that required from strength consideration alone, is used. Minimum cement content of 400 kg/m$^3$ and a maximum water cement ratio of 0·45 shall be maintained for all grades of concrete for RCC and prestressed concrete construction. However, for trimmed concrete, the maximum water cement ratio can be relaxed up to 0·5 at the discretion of the engineer-in-charge. In case of plain cement concrete, a minimum cement content of 310 kg/m$^3$ and a maximum water cement ratio of 0·5 shall be maintained.

**8.3.4** As cracking in concrete members is to be minimized, reduced stresses are recommended for concrete and steel to be used in the design of RCC members subject to marine environments unless the structure is checked against the formation of cracks. The stresses in steel may be reduced to 165 N/mm$^2$ in working stress design. As a guide, assessed surface width of cracks at points nearest to the main reinforcement should not exceed 0·004 times the cover of the main reinforcement.

**8.3.5** Adequate thickness of cover is to be provided for the structures in marine atmosphere. It is recommended for structures immersed in sea water, in splash zone, or exposed to marine atmosphere, that the thickness of cover should be 25 mm more than the cover specified according to **25.4.1** of IS 456 : 1978.

**8.3.6** The use of precast concrete elements is preferred for marine structures as they are cast under strict quality control and, therefore, are able to withstand the destructive influence of marine environments better.

**8.4 Timber**

**8.4.1** Timber has wide use in dock and harbour structures. It can be used for sheet piles, bearing piles, structural members in jetties, fenders, transit sheds and warehouses, as structural members and/or for door and window frames.

**8.4.2** The hazards which face timber are the attack by fungi and insecticides; and in sea water the attack by the marine borers. When used in dockside buildings the design shall be primarily guided by provisions of the relevant standards and protection against the attack of fungi and insecticides. The timber used in marine structure, particularly if subjected to fluctuating tides, is prone to attacks by marine borers and require preservative treatment.

**8.4.3** An effective preservative treatment of timber is creosoting which is normally applied by pressure impregnation ( *see* IS 401 : 1982 ).

## 9 FENDERS

**9.1 Purpose**

The fenders shall absorb the impact of berthing vessel and also the chatter of the moored vessel in order to avoid damages to the vessel and to the structure. Functionally, fenders shall accomplish the following purposes:

a) Absorb the berthing energy or impact of vessels and transmit a designed or calculated thrust to the structure,

b) Hold the vessel off the face of the structure and avoid rubbing against the structure and consequent damages to the vessel and the structure, and

c) Impart the thrust from berthing loads to the structure at predetermined or design points.

**9.2 Type of Fenders**

The fenders may be made of rubber, steel, timber, brushwood, rope, concrete and similar material. Rubber has come into extensive use for fender system. Amongst various types, there may be hollow-cylindrical or rectangular rubber fenders, sandwich type known as Raykin fender buffer, steel spring fenders, wood-springing-type fenders, horizontal and vertical timber fenders, fender piles, brushwood fenders, gravity-type fenders, torsion fenders, floating fenders, obstruction types, etc. The choice of material and the type of fender shall be judiciously made to serve the specific purpose in the particular case.

**9.3 Design**

The design of the fenders shall be dependent on the following parameters and they should be designed for berth loads from ships as specified in IS 4651 ( Part 3 ) : 1974.

a) *Size of Ship*

The fender capacity shall depend upon the ship size and also on the frequency of arrival.

b) *Berthing Velocity*

The berthing velocity under various conditions and type of vessel shall be adopted as specified in IS 3651 ( Part 3 ) : 1974.

c) *Importance of Structure*

The design of the fenders shall take into account the importance of consequences suffered by the ship and the berthing structure in case of an eventual accident due to insufficient energy absorption capacity.

d) *Energy Absorption*

Various types of fenders absorb energy in various ways but in most of them, the kinetic energy of the ship is stored in energy of strain. Shear permits the absorption of larger amount of energy than tension and compression. Flexure does not permit an efficient use of material as only a small percentage of the material of the fender may reach the allowable stresses. Torsion permits a good use of all the materials of a fender, particularly if tubes with thin walls are used.

The flexibility of the berthing structure together with that of the fendering system may be taken into consideration in computing the total energy absorption capacity of the whole system. Any accepted method of analysis ( such as beams on elastic foundation ) may be adopted for such computation.

e) *Reaction Force and Deflection of the Fender*

The maximum amount of reaction force of a fender system on ship shall be chosen taking into account:

1) the strength of hull, and

2) the strength of the berthing structure.

The manufacturers of proprietory fenders usually supply the energy absorption, deflection and reaction force characteristics of the specific fenders. These should be adopted in design. It is, however, recommended that a factor of safety of 1·4 should be applied over the ultimate energy absorption capacity of such fenders.

f) *Disposition of Fenders*

The disposition of the fenders shall depend upon the location of the berths, the type of berthing structure, conditions of berthing, etc. However, as a general rule, the longitudinal spacing should not exceed 0·3 to 0·4 $L$ where $L$ is the length of the smallest ship; the remaining length of the berthing face shall be provided with secondary fenders for the use of smaller vessels. The vertical disposition shall be so designed as to prevent the ship's hull and/or berthing structure being damaged under all tidal conditions and in specific cases, may extend from the cope level to the low water level.

## 10 EXPANSION JOINTS

**10.1** A sufficient number of expansion joints shall be provided depending upon the type of the structure, the sub-soil and the atmosphere conditions in order to accommodate movements arising from shrinkage, temperature changes and some yieldings of the foundation. The steel reinforcement shall be so designed that it also acts to provide the shrinkage and temperature cracks.

**10.2** As a general rule, a length of 39 m between the expansion joints is recommended for structures, such as solid quay walls or walls resting on piles. A spacing of 60 m provides better stiffness.

**10.3** The expansion joints in the sections shall be keyed for mutual transfer of shear force and shall be so designed that changes in the length of the sections are not hindered. The arrangement of keys for vertical support shall depend on the soil conditions, the construction of the structure and the type of its loading. The expansion joints shall be covered to prevent the backfill from being washed out.

# ANNEX A

( *Clause* 2.1 )

## LIST OF REFERRED INDIAN STANDARDS

| *IS No.* | *Title* |
|---|---|
| IS 226 : 1974 | Specification for structural steel ( standard quality ) |
| IS 401 : 1982 | Code of practice for preservation of timber ( *third revision* ) |
| IS 455 : 1976 | Specification for portland slag cement ( *third revision* ) |
| IS 456 . 1978 | Code of practice for plain and reinforced concrete ( *third revision* ) |
| IS 800 : 1984 | Code of practice for use of structural steel in general building construction ( *second revision* ) |
| IS 875 ( Part 3 ) : 1987 | Code of practice for design loads ( other than earthquake ) for buildings and structures : Part 3 Wind loads |
| IS 883 : 1970 | Code of practice for design of structural timber in building ( *third revision* ) |

| *IS No.* | *Title* |
|---|---|
| IS 1343 : 1980 | Code of practice for prestressed concrete ( *first revision* ) |
| IS 1489 : 1976 | Specification for portland pozzolana cement ( *second revision* ) |
| IS 1893 : 1984 | Criteria for earthquake resistant design of structures ( *fourth revision* ) |
| IS 2062 : 1984 | Specification for weldable structural steel ( *third revision* ) |
| IS 2911 ( Part 2 ) : 1980 | Code of practice for design and construction of pile foundation: Part 2 Timber piles ( *first revision* ) |
| IS 2911 ( Part/ Sec 1 to 3 ) : 1979 | Code of practice for design and construction of pile foundation: Part 1 Concrete piles<br>Section 1 Driven cast *in-situ* piles<br>Section 2 Bored cast *in-situ* piles<br>Section 3 Driven precast concrete piles |
| IS 4651 ( Part 3 ) : 1974 | Code of practice for planning and design of ports and harbours: Part 3 Loading |
| IS 7314 : 1974 | Glossary of terms relating to port and harbour engineering |

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